GRETA: Utilizing New Concepts in γ-Ray Detection

M.A. Deleplanque, I.Y. Lee, K. Vetter, G.J. Schmid, F.S. Stephens, R.M. Clark, R.M. Diamond, P. Fallon and A.O. Macchiavelli*
Nuclear Science Division, Lawrence Berkeley National Laboratory
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We present a new concept for γ-ray detector arrays. An example, called GRETA (Gamma-Ray Energy Tracking Array), consists of highly segmented HPGe detectors covering 4π solid angle. The new feature is the ability to track the scattering sequence of incident γ rays. This potentially allows one to measure with high resolution the energy deposited, the location (incident angle) and the time of each γ ray that hits the array. GRETA will have a resolving power of order 1000 times that of Gammasphere-type detectors.

The GRETA principle is as follows. GRETA consits of a "solid" shell of (about 100) highly segmented large HPGe detectors. The outer contact (surface of the coaxial detector) is segmented into many "rectangular-like" areas. The full energy and angle with respect to the beam direction of each incident γ ray are determined by measuring, with high resolution, the energy and position of each of its interactions in the Ge crystals. The incident γ ray is reconstructed by identifying these interactions using a tracking algorithm based on the Compton-scattering formula which describes the interactions. The γ-ray energy is obtained by adding the energy deposited at each interaction, and the emission angle of the incident γ ray is deduced from the position of the first interaction. Using fast transient digitizers, an additional gain in efficiency comes from the reduced dead time. In addition, it is expected that, using parallel processing, this analysis can be done in real time.

The improvement over previous arrays comes from the following three areas. (1) The efficiency is increased because nearly 100% of the solid angle is occupied by Ge detectors which provide a useful high-energy resolution energy signal (instead of 46% in Gammasphere for example) and, in addition, most γ rays Compton scattered to another crystal can be recovered. (2) Because of the high segmentation each γ-ray interaction can now, in principle, be resolved and attributed (by tracking) to a particular incident γ ray, thus improving the signal to noise (full-energy to partial-energy) ratio. (3) Since the interaction-position resolution is high (of order 2 mm), the position of the first interaction of a γ ray will give its direction from the target with a corresponding precision and the Doppler broadening effects due to finite detector size will be greatly reduced.

The "proof of principle" for such an array is almost complete. The achievement of a high interaction-position resolution (~1-2 mm) depends on the ability to interpolate the segment size (~ 1-2 cm) using transient charge signals from neighboring segments. Tests performed on a 12-segment prototype show the expected sensitivity of the transient signals to the interaction position. A 36-segment prototype is ordered (see figure) and should allow the determination of the operational position resolution. A tracking algorithm has been implemented and performs reasonably well. More work needs to be done to finalize the design of such an array.